UNIVERSITY OF CALIFORNIA—COLLEGE OF AGRICULTURE.

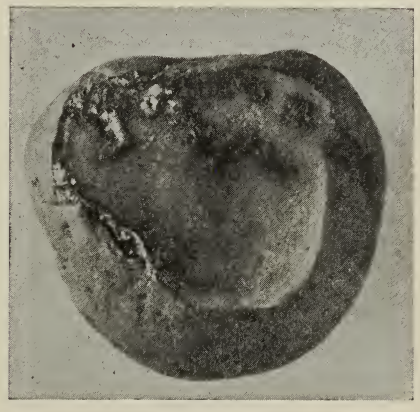
AGRICULTURAL EXPERIMENT STATION.

E. W. HILGARD, Director.

THE POTATO-WORM IN CALIFORNIA.

(*Gelechia operculella*, Zeller.)

BY WARREN T. CLARKE.



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THE POTATO-WORM IN CALIFORNIA.

(*Gelechia operculella*, Zeller.)

By WARREN T. CLARKE.

NOTE.—The present paper has been prepared in accordance with the policy of permitting properly qualified students of the Agricultural Department to take part in the actual work of the Experiment Station. The insect treated is probably the most injurious species attacking truck crops in the State, but has hitherto received but little attention by entomologists. The study here reported constitutes a very material advance in our knowledge of the life history and habits of the insect and of the problem of its control.

C. W. WOODWORTH, Entomologist.

The most serious potato pest in California is the potato-worm (*Gelechia operculella*, Zell.), a widely distributed insect also known in the Southern States as the Tobacco Leaf Miner or Split-worm.

The damage to the potato crop in California, as estimated by the writer on the basis of opinions obtained from a large number of growers and dealers, aggregates in some years fully twenty-five per cent.

In one section where some of the finest of potatoes are grown, the Salinas Valley, the dealers estimate that at times the loss has gone as high as 40,000 sacks in a single year, and indeed the potatoes from any section of the State have to be watched carefully by the dealers to avoid wormy lots. This need of care is because of the fact that a very few wormy potatoes may infect in a few weeks a whole storeroom full of what were originally clear tubers. As the potato is a food product that is expected to retain its value for many months, this possibility of infestation becomes a most serious question. Certain rots, particularly that produced by a species of Penicillium*, follow the work of the worm, starting in the burrow filled with excrement and ultimately involving the whole tuber.

Potatoes for the Philippine and Hawaiian trade require very careful culling before shipping, because the warm, moist conditions on the voyage into the tropics favor both the insect and the fungus, a single infested potato often spoiling a whole crate.

The injury to the plant in the field, though not as large in the aggregate as that to the potatoes in storage, occasionally results in the total loss of the crop.

*Specimens examined by Mr. O. Butler, of this laboratory, show the presence of a red yeast, a species of Mucor, and of Penicillium, this latter distinctly predominating.

The cause of this loss is not generally recognized by the grower, who commonly designates it as a "mould," "rust," or "fungus." While it is difficult to deal with in the field, yet it can be controlled even there. This failure to recognize the cause has been an important factor in the spread of the trouble.

The injury produced by the worm is extremely evident to the housekeeper and is well known to all dealers in potatoes; but very generally they do not understand the nature of the insect producing the trouble. Among the commonest misconceptions may be mentioned the idea that it is a form of rot not associated with any insect. Usually, however, the work of the worm is recognized as such, but its connection with any other stage of existence is unknown or misunderstood. The importance of knowledge on this subject rests on the fact that the carelessness of a grower or dealer stands as a constant menace to all the potatoes in the neighborhood.

Though the potato-worm is so injurious in California, and occurs in the East and in many parts of the old world, it appears to be quite unknown in any of the adjacent States, or at least does not appear in sufficient number to cause any marked damage. The Station entomologists of Arizona, Nevada, and Oregon each have written us that the insect has not come to their personal notice.

The insect has long been known to be greatly injurious to solanaceous plants, and has been described by various authors under various names. In all cases where the food habit has been noted, however, it has been found to be working on some one of the Solanaceæ, and in no case on plants of any other family. This restriction of an insect to one food-plant is very common, and in the present case at least simplifies the work of control, but also opens the way for its preservation in the wild plants of the favored family. We find the insect in many cases doing great damage to the tobacco plant (see U. S. Dept. of Agric. Farmers' Bulletin No. 120, etc.), and it is as a tobacco pest that it has been most noted in this country. Its work in California, however, is on the potato, and this bulletin is confined to its damage to that plant.

Bibliography.—The insect was first described by Zeller in 1873 in his Beiträge zur Kenntniss der Nordamerikanischen Nachtfalter, 62, under the name *Gelechia operculella.* The type specimens from which this description was made were received from Texas.

In November, 1874, Boisduval redescribed the insect in Jahrbuch Soc. Cent. Hort., under the name *Bryotropha solanella.* He noted that it caused great damage to potatoes in Algeria, and stated that the eggs were laid upon the young plant, and that the larvæ on hatching burrowed into the stem and then down and through the tissue of the stem into the tuber. This passing of the larvæ through the stem into the

tuber is probably incorrect, as it was in no way confirmed by the present experiments.

The next reference made to the insect was by Ragonot, in 1875, in the Bulletin Soc. Ento. France, 5 (v), pp. xxxv–xxxvii, in which he redescribed the insect under Boisduval's original name, with remarks upon its injuries.

In March, 1878, V. T. Chambers, of Covington, Ky., in the Canadian Entomologist, Vol. X, pp. 50–54, redescribes the insect under the name *Gelechia solaniella*, and notes it as mining the leaves of *Solanum Carolinense*.

In 1879, Ragonot, in the Bulletin Soc. Ento. France, pp. cxlvi–cxlvii, again described the insect under the name *Gelechia tabacella* as a tobacco pest.

In 1880, Meyrick, in an article in Proc. Linn. Soc., New South Wales, Vol. IV, pp. 112–114, treats the insect as a potato pest under the name *Gelechia solanella.*

In 1883, Matthew Cooke, in his book "Injurious Insects of the Orchard, Vineyard, Field, etc.," pp. 313–315, notes the insect as having been observed by him in California as early as 1881. He states that "the moths appear about the first of July and deposit their eggs in potatoes after the latter are gathered from the ground and placed in heaps or sacks," and recommends close covering the potatoes after digging as a preventive of infestation.

In 1886, Meyrick makes further notes on *Gelechia solanella* in Trans. New Zealand Institute, Vol. XVIII, pp. 166–167.

In 1889, Mr. Henry Tryon, in his Report on Insect and Fungous Pests, pp. 175–181, treating of the insect in Queensland, quotes from a correspondent of his, Mr. G. Searle, the statement: "The uppermost potatoes, those which are nearest the surface, are of course most easily reached, nor is it by any means a difficult matter for the insect to penetrate to the depth of three or four inches when the soil is open, uncompressed, or lumpy"; and again, "The potatoes, whilst lying exposed in rows, were attacked by the insects." These statements are worthy of note, because of their economic bearing, and they were fully confirmed by the present inquiry.

In September, 1892, the Government Entomologist, Mr. A. Sydney Olliff, in the Agricultural Gazette of New South Wales, reports the insect as a tobacco pest in that colony.

In the same year, Riley and Howard, in Insect Life, Vol. IV, Nos. 7 and 8, pp. 239–242, figure and discuss the insect quite fully, referring to its presence in California, and suggesting that it might have been brought by Chinese gardeners from China. Under the head of remedies, "the immediate destruction of the infested potatoes" is urged, as is also the careful packing or storing of the sound potatoes in tight rooms.

Again, in the same year, Riley discusses the insect in the report of the Secretary of Agriculture, pp. 156–157, and sounds a note of warning in these words: "The undue presence of so serious a pest in California calls for energetic measures. All infested potatoes, wherever found, should be immediately destroyed, and receptacles in which they have been stored should be treated with kerosene. Sound potatoes should be stored in tight rooms." This is good advice indeed, but since it has seldom or never been followed the pest has increased.

The only other reference noted is an article by Dr. L. O. Howard, in the Department of Agriculture Year Book for 1898, pp. 137–140, where the insect is treated of as a tobacco pest; a revised reprint of which appears in U. S. Department of Agriculture Farmers' Bulletin No. 120, pp. 19–22.

The above (by no means complete) bibliography of the insect shows that it is widespread and very injurious to solanaceous plants. It has been described from different parts of the world under various names, but probably Zeller's naming, *G. operculella*, holds, on account of priority.

We here give a partial synonymy of the insect, furnished by Lord Walsingham, and copied from the U. S. Department of Agriculture Farmers' Bulletin No. 120, p. 22:

Solanella Bdv.

Gelechia terella (a homonym), Wkr., Cat. Lp. Ins. B. M., XXX, 1024 (1864). *Bryotropha solanella* Bdv., J. B. Soc. Cent. Hort. 1874; Rag., Bull. Soc. Ent. Fr., 1875, XXXV–XXXVII. *Gelechia tabacella* Rag., Bull. Soc. Ent. Fr., 1879, CXLVI–CXLVII. *Gelechia solanella* Meyr., Pr. Lin. Soc. N. S. W., 112 (1879); N. Z. Jr. Sc., II, 590 (1885). *Lita tabacella* Rag., Bull. Soc. Ent. Fr., 1885, CXI–CXII. *Gelechia solanella* Meyr., Tr. N. Z. Inst., XVIII, 166–167 (1886). *Lita solanella* (Olliff), Agr. Gaz. N. S. W., II, 158–9 (1891).

GENERAL DESCRIPTION.

The nearest relative that we have to this insect that is injurious to crops is the peach-worm (*Anarsia lineatella*), whose ravages are well known to and dreaded by the peach-grower. Both this insect and the potato-worm, as well as most of the moths belonging to this family, are of small size, with narrow, well-fringed wings; very delicate and generally of quite subdued coloration.

The potato moth is grayish-brown, with ochreous tints intermixed. Under magnification it appears to be dusted over with white and black specks. The brown and ochre of the anterior wings is in the form of more or less regular longitudinal bands. These bands, varying in relative size in different specimens, cause a certain amount of variation in color to appear. The general color-effect of the posterior wings is similar to but lighter than that of the anterior wings. Both sets of wings are well fringed, the posteriors having longer fringes than the anteriors. The antennæ are rather prominent, and are inserted just anterior to the center of the compound eyes. The palpi are prominent,

gray-brown externally and dusty yellow internally. When at rest the wings are folded somewhat roof-shape over the abdomen, and when in this position the length of the insect is about 8 mm. ($\frac{1}{3}$ in.). With wings expanded the insect measures from tip to tip 16 mm. ($\frac{2}{3}$ in.). The illustrations of the insect (Fig. 1) give a very fair idea of its general appearance. Other members of the group differ from it in minute characters that would be noted by an entomologist, but are not found in the same situations. They are quite quick flyers, and are easily recognized in storerooms by their rapid flight toward the light when they are disturbed. The female is somewhat larger and more robust than the male.

FIG. 1. Adult moth of potato-worm (*Gelechia operculella*, Zell.). Actual size shown by hair line.

The Egg and Oviposition.—The egg is about $\frac{1}{4}$ mm. in diameter and $\frac{1}{2}$ mm. long. It is of an oval shape, and shows under the magnifying glass the color-play of pearl, its general color being a shining white. Its extreme minuteness and the fact that it is placed in the most inconspicuous positions available render it difficult of detection. We present a microphotograph (see Fig. 2) of a number of the eggs *in situ* about the eye of a potato, which gives a fair idea of their general appearance. The magnification is twenty diameters. The female depositing these eggs was placed in a jar with one thoroughly cleaned potato and was observed in the act of oviposition. She always sought the eye of the potato as the place to lay the egg. Having found a position that seemed to suit her, she settled down flat on the surface at this place, and remained quiet for two or three minutes. Then a drawing of the tip of the abdomen toward the thorax, ventrally, was observed and the

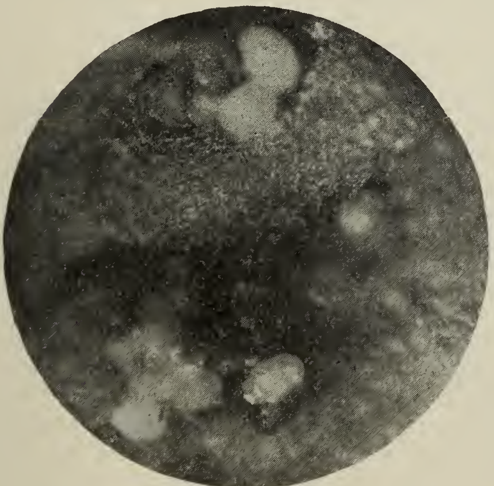

FIG. 2. The Egg. Enlarged twenty diameters.

egg was extruded. The process was repeated for, in one case, three times without any apparent change of position. Generally, however, not more than two eggs were placed contiguously, and in the majority of cases they were placed singly. This particular female laid 22 eggs that were observed. The eggs are viscid externally at first, but they quickly dry and remain glued in position. The position sought by the female for placing the eggs, e. g., the eyes or buds of the potato, presents a satisfactory place of concealment for them, and is also the place where the epidermis of the potato is more easily penetrated by the young larvæ than at any other point.

Larva.—On hatching, the larva is 1 mm. long and of a transparent white color, with the head and thoracic region darker. Its minuteness

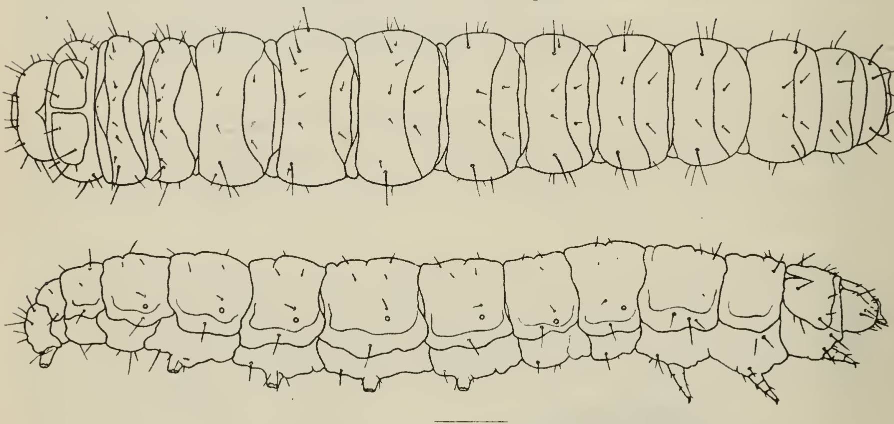

FIG. 3. **Larva. Hair line indicates natural size.**

renders it difficult of observation, and it is only noticed by the ordinary observer after its second or third molt. At this stage it is quite noticeable, being from 5 to 6 mm. long. The head is characteristically of a dark brown color, with the mouth parts well developed. The first thoracic segment is of a clouded pink ("old rose") color, colored over dorsally with the dark mahogany-colored cervical shield. The second thoracic segment shows the clouded pink color both dorsally and ventrally, and the third thoracic segment is clouded white, as are the seven following abdominal segments. This clouded white color may verge to yellow and to green; this color-change being dependent on whether the larva has been feeding on the heart of the potato or on greener material near the surface. Frequently these abdominal segments will be suffused dorsally with pink. The eighth (terminal) abdominal segment is of a shining yellow color. The various segments are ornamented with sparsely scattered hairs or spines.

The position and appearance of the thoracic as well as of the abdominal legs are shown in Fig. 3.

The Chrysalis and Pupation.—The chrysalis is 6 mm. long, and is at first a light yellow, turning very soon to a rich mahogany and finally to a dark mahogany color. The abdominal segments are conspicuous, and to a late stage in the chrysalis's life are quite free in movement. The wing-folds are free from the abdomen distally; the ventrally-placed antennæ are quite well defined; the eyes prominent. Fig. 4 is a good representation of the chrysalis.

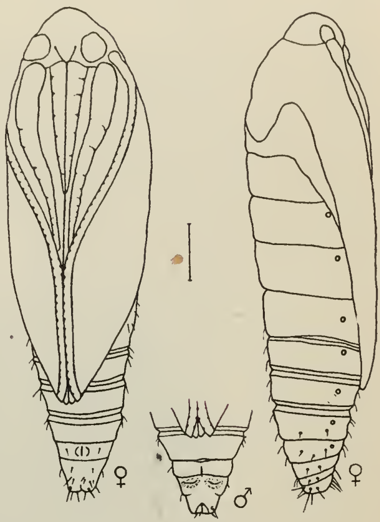

Fig. 4. Chrysalis.

The pupation of the insect is interesting, and can be observed satisfactorily. The larva at about six weeks age comes to the surface and either pupates in the mouth of its burrow after it has broken through the epidermis, or seeks some depression on the potato, or may find its way into some crack or cranny of the receptacle in which the potatoes are stored. It has been frequently observed, during this investigation, to find its way into the fold of the sack in which the potatoes are kept. Generally speaking, then, the

Pupa case closed. Fig. 5. Pupa case open.

worm finds a more or less secluded place and there pupates. The satisfactory spot having been chosen, it proceeds to spin its silken cocoon therein. A carpet piece of silk is well fastened to the

surface, the cover piece being woven at the same time, the two together forming a sort of pocket, smooth and white on the inner side, but on the outer side covered with bits of frass, trash, etc., and assuming the appearance of a piece of dirt and nothing more. When this covering is arranged satisfactorily externally the worm gets beneath it and sews together the opening remaining at the end of the pocket, and transforms to the chrysalis in safety within it.

Fig. 5 shows a pupa case placed within a very slight depression to conceal it, and also the same pupa case with the cover torn loose and turned back and the chrysalis in sight; while Fig. 6 shows, at the end

FIG. 6. Pupa case in wound caused by Stenopelmatus.

of the pin, a pupa case, with the chrysalis exposed, in a wound in the potato caused by the yellow ground cricket (*Stenopelmatus* Sp., fig. 10). The pupa cases are generally so cunningly concealed beneath their bits of dirt and trash that they may easily pass unnoticed, but they are quite pervious to air and are easily destroyed. (See Remedies, p. 27.)

LIFE HISTORY.

A series of observations covering the life of the insect for nearly eleven months was taken. Two lots of moths were studied concurrently, and the results seemed to agree in the main points. A lot of young potato plants, stalks and leaves, with very small potatoes, was obtained and kept in a gauze-covered case. The stalks were much infested with the larvæ, and as these stalks wilted the larvæ worked their way out of them and across the intervening space of 10 cm. (4 ins.) and into the small tubers. They continued to work here until ready to pupate, and then came to the surface and placed their chrysalides in depressions on the potato. The age of the larvæ in the stalks was not known, but the first to pupate tunneled out of the potato on the fifth day after entering, and in eight days all had pupated. On the thirteenth

day after pupation the first moth emerged, and on the sixteenth day all had emerged. This gives the period of pupation in this generation as from thirteen to sixteen days. The adult moths can carry on the life functions without eating, and hence breeding in storage is quite easy.

The moths mated soon after emerging, and oviposition was noted on the second day after emergence. The first larvæ noted were recognized eight days after oviposition, and new larvæ appeared on the two following days. These young larvæ were carefully observed, and forty-two days later they began to come out of the potato and to pupate, and continued to appear for three days thereafter.

The second lot of moths was carried much further than this lot, and their history is as follows: A lot of infested potatoes was purchased from a dealer, and on September 17, 1900, nine moths were taken from this lot and placed with some uninfested potatoes; on the 18th, the copulation of two pairs was noted; on the 20th, three females were noted ovipositing (see Oviposition, p. 9). On September 28th three larvæ were noted; on the 29th six larvæ, and on the 30th five larvæ. On November 12th two larvæ came to the surface and made cocoons; on the 13th six larvæ went into this condition; on the 14th twelve more, and on the 15th six more. On November 28th three moths emerged, on the 29th seven moths, on the 30th eight moths, on December 1st seven moths, and on December 2d one moth. On December 2d a number of moths from this generation were placed in breeding cages with uninfested potatoes, and on December 3d oviposition was noted. On December 10th larvæ were recognized, and these larvæ began to spin up on January 21, 1901, and by January 23d eighteen cocoons were noted. On February 7th the moths had begun to emerge, and on February 8th fourteen adults were noted. This gave about the same time for this generation to complete its cycle as in the previous case.

The same process of placing the moths with uninfested potatoes was repeated and the same results obtained, save in the case of the larvæ, where the life period was extended to nine weeks (a sort of hibernation?), and adult moths appeared on the 4th day of May, 1901. Again was the process repeated, and a new lot of moths appeared on the 9th of July, when the breeding was abandoned.

We may summarize the life history thus: To complete the cycle ordinarily, 63 to 69 days are needed, save for the winter generation when this time may be extended to 84 or 85 days; this, of course, under the temperature conditions of Berkeley. This time is divided thus: Egg stage, 7 to 10 days; larvæ, 42 to 45 days ordinarily, winter generation 9 weeks; chrysalis, 14 to 16 days; adult life, indefinite but short.

This study of the life of the insect is significant from the fact that the conditions for living and propagating were the same as are found when potatoes are stored, and the result indicates conclusively that the injury

is progressive. A very small primary infestation may in a few weeks mean the complete ruin of the infested lot. Also, it is to be noted that the adult moth is ready for the young potato plants as soon as they appear in the spring. Under storage conditions the generations will not be so clearly defined as in the laboratory conditions, and there will be an apparent lapping-over of broods, and adults will be noted at all times. This "lapping-over" of course results in the adult being ready to do damage at almost any time that material is presented for it to work upon. The necessity is obvious, therefore, of destroying the moth in infested storerooms, bins, etc., and not permitting it to escape and spread the infection. This aspect of the case will be treated of more fully under the heading of "Remedies."

CHARACTER OF INJURY.

The injury done by the insect naturally falls under two heads: the injury to the growing plant and the injury to the tubers. The character of the injury in the first case, that of to the plant, has been touched on on page 5, and is perhaps not so often noted as is the injury to the tubers. When the moth oviposits on the plant she seeks some desirable position, such as the base of a leaf, in which to place the egg, and the young larva on hatching immediately burrows beneath the epidermis of the plant and eats its way along downward, always just beneath the epidermis. This burrow can be quite easily traced when the larva begins to attain some size, and by careful search can be detected even when the larva is quite young. The worm fills the burrow behind itself with excrement, and this ejected material turns quite dark in color. Following in the wake of this primary injury is the inevitable mould and fungous growth, and the stalk soon succumbs to the combined injuries, the actual material taken as food by the worm and the consequent decay.

FIG. 7. Sub-epidermal burrow.

The injury to the tuber is very similar to that to the plant. The worm enters the potato and burrows its way through the tissue of the tuber. This entry is in the bud, and the point of entry is generally marked by a little pile of excrement. The worm having succeeded in entering, tunnels along beneath the epidermis or right through the substance of the potato. It does not seem to be at all particular which method it follows, and indeed may show both kinds of work. When

the burrow is sub-epidermal it may be easily traced by the shrinkage of the potato on either side of it, as is shown in Fig. 7. When the burrow is in the substance of the potato it is very evident and can be easily traced by the discolored excrement. The frontispiece illustrates both kinds of work. The potato has been cut in such a way as to show both a sub-epidermal burrow and also certain burrows into the body of the potato. These burrows are filled with excrement, and render the potato wholly unfit for human food. The burrows, with their excremental filling, soon become the starting points for rots and fungous diseases, as previously noted (p. 5), and the injury is complete.

MODES OF INFECTION.

There are various ways in which the potatoes may become infected, and these ways may be described in this order:

By infection of the stem: The adult female moth, being on the wing when the young potato plant appears above the ground, oviposits on the plant itself at a point near the junction of a leaf with the stem. The larva hatches and immediately begins work by "mining" a burrow beneath the epidermis. The general trend of this burrow is downward, though a spiral course may be pursued. If the attack has been made on a very young plant the larva may come to maturity and work its way out of the stem and pupate in the ground beside the plant or in some depression in the stalk itself. In this case the tuber is not injured, but the plant suffers both because the nutriment has been taken from it and also because of bacterial and fungous diseases bred in the excrement with which the burrow is filled. Cases have been reported to us where hundreds of acres of potatoes have been wholly lost through an attack of this kind. If the oviposition takes place in an older plant, the larva burrows down the stalk as before, but the hardening of the plant causes it to leave and enter a tuber and continue operations there. This entry is generally made near a bud or eye, and the larva actually passes out of the stem and through the surrounding earth to the tuber, and not down the stem and into the tuber, as is generally stated. On infested plants observed in the laboratory the larva left the stalk and crossed over the space of one decimeter (4 inches) of earth to potatoes placed at this distance from them. When the larva had found the potato it would wander about the surface for some time, twenty-four hours in some instances, but seemed to have no difficulty in finally piercing the skin and entering.

By direct infection of the tuber in the hill: In the experimental plot it was noted that in many cases there were tubers that were not completely covered in the "hilling" process. The exposed portions of these

tubers, being open to the light, turned green, and the moth oviposited in these green places. The fact that the fully covered tubers in the same hill were entirely free from the larvæ, and the further fact that in some cases remnants of the egg were found in these green places on the potatoes, shows the direct infection in the hill.

Direct infection after digging: The moth will oviposit in the potatoes that are left exposed in the field after digging. Many perfectly clear tubers were so exposed, and in the large majority of cases these tubers were later found infested; in one case five larvæ were taken from one potato.

Indirect infection after digging: If the stems are infested at the time of digging, the larvæ will leave them and find their way to and enter the tubers, if these are available. The common practice in the potato fields of covering the piles of newly dug tubers with the leaves and stems of the plants by way of shade is a sure way to secure infestation if the latter contain larvæ. Even though the leaves and stems may be uninfested the practice of using them as a covering is not to be commended, as when they are used for this purpose they also furnish a place of concealment for the moth in close proximity to the tubers.

Infection in the sack or bin: The moth will oviposit on the stored potatoes. A number of clear tubers were placed in a gauze-covered box, and a lot of the moths placed with them. Infestation always followed this experiment.

EXPERIMENTS IN FIELD OR STOREROOM.

The experiments here detailed were carried on with the surrounding conditions made to conform as nearly as possible to the natural conditions. The field work in all its aspects was a duplicate of the ordinary farm conditions, and the laboratory work might well pass for a series of experiments carried on in storerooms. It is believed that the field results obtained can be obtained in regular farm practice, and that any one storing potatoes can duplicate the results obtained in the laboratory. As a matter of course, great care was exercised, not alone in carrying on the experiments, but so far as possible this was done with a view to the expense account, and no work requiring a heavy outlay was attempted, nor would such be required in commercial practice. Infested potatoes were purchased in the open market and used for laboratory experiments, as well as the product of a patch of sound potatoes planted on the Station grounds. This patch and its product served as a basis for much of the field observation and experiment, and this work at the Station was supplemented by studies made in large fields of infested potatoes and by observation and inquiry in the warehouses and storerooms of many

dealers. Whenever cases were reported that appeared to present features of value in this inquiry no pains have been spared in investigating them, and as a result we are able to present a fairly complete account of the insect and its work in California, which knowledge, if applied in handling potatoes, should cause a marked diminution in the loss from the work of the insect.

Field Experiments.—On March 7, 1901, the experimental patch of potatoes was planted on the Station grounds in Berkeley. The soil is a medium heavy loam, and was well plowed. The seed-potatoes used were Oregon Burbanks, and were perfectly clear of infestation. The season was rather cool, and the potatoes did not appear above ground until April 1st. By the end of April the plants were growing well and were quite thrifty. Scarcely any plant-infestation was noted up to this date, though to insure, if possible, such infection a number of moths, bred in confinement, were liberated in the patch on April 5th. Whether these were the moths that were instrumental in infecting the plants is of course open to question; however, on April 25th six affected plants were noted, and on two of these remnants of the eggs were found. The affected stalks were cut off and destroyed in these six cases, and the result was a complete stoppage of the trouble with these plants. The plants seemed to suffer in nowise from this lopping-off process, and when these hills were dug it was found that the yield was up to the average of surrounding hills. It must not be understood that the whole head was removed in these six cases—only the affected stalks were cut off just below where the trouble was manifest. On the night of April 25th, after the affected stalks had been noted, an experiment was tried with a crude lantern trap, and in one hour fourteen of the moths were taken at one candle. The trap was merely a small sheet of bright tin used as a reflector, and a candle set up in a basin of water on which a little kerosene oil was floating. This trap was tried subsequently a number of times, and demonstrated beyond a doubt that the moth can be destroyed in large numbers by the use of light-traps. It is interesting to note in this connection that more potato moths than of all other species combined were taken, and that the majority (60%) of the potato moths taken at this trap were females; and since one female lays many eggs and can infect many plants, the value of this method of destruction is evident. It was not desired to reduce the moths to below the danger limit on this patch, so the light-experiments were at no time carried on for more than an hour. The moths taken at the light certainly came from the surrounding locality, the date of capture as well as their numbers precluding the possibility of their being those originally turned loose in the patch, and it was also too soon for their progeny.

As the worm, on hatching, at once burrows into and feeds upon the tissue of the plant, and as the egg is laid where it is difficult to reach with sprays, no experiments along this line were made.

The next field experiments tried were when the potatoes began to form and the time of hilling arrived. The earth about a number of plants was well pulverized, and this specially pulverized earth used to hill with. The result was a good, compact hill, with the potatoes well covered and difficult for the moth or worm to get to. When the potatoes were dug from these hills no infestation was found in them, though the check hills on either side were infested. These check hills were "hilled" in the ordinary way, and the earth here being quite cloddy certain of the potatoes were somewhat exposed. In every case of such exposure it was found that the potato was infested. In certain of the hills the earth was scraped away so as to expose one or more of the potatoes to the light. The exposed parts of the potatoes turned green, and it was found in every case that these potatoes were infested and that the work of the worm began in this green part. Likewise, taking the whole field when the potatoes were finally dug, it was found that 95 per cent of the ones showing green places were infested, and that the infestation in every case began in these green places. Furthermore, in all cases where potato fields were found infested it was noted that this rule held—that the soil was either lumpy and the potatoes exposed more or less, or was fine and dry, quite sandy for instance, but not compact. In either case the potatoes were easy to reach.

Again, it has been noted in the course of this investigation that right in the midst of affected fields a field will be found in which the tubers are not affected, and invariably the reason of this non-infestation has been found to be the careful hilling of the plants. It has further been noted that a rain coming after hilling, as occasionally happens, has a tendency to compact the earth, and the potatoes which were covered in these compacted hills were unaffected. Indeed, all the experimental work and all the field observations point to the fact that *careful compact hilling reduces the infection to a minimum*, and too much emphasis cannot be put upon this phase of farm practice.

Finding that the potatoes exposed in the hills were almost invariably infested led to a series of experiments on the question of exposure. It was noted that in ordinary farm practice the potatoes are frequently left exposed for varying times when digging was in progress, and a number of potatoes known to be uninfested were left exposed in the field for times varying from two to ten hours in daylight. The following table gives the results of this experiment:

Table Showing Results of Exposure Experiments.

Lot.	Number of Potatoes.	Time of Exposure.	Hours Exposed.	Number Infected.	Percentage of Infestation.
A	40	8 A. M. to 10 A. M.	2	1	2.5
B	40	8 A. M. to 12 M.	4	4	10.0
C	40	8 A. M. to 2 P. M.	6	9	22.5
D	40	8 A. M. to 4 P. M.	8	17	42.5
E	40	8 A. M. to 6 P. M.	10	29	72.5

It will be seen from this table that a very small percentage of those potatoes which were exposed for the shortest time, two hours, were infected, and the increase in infection shown in the second lot, B, where the exposure was two hours longer, is not large. The rise in per cent of infection shown in lots C, D, and E is significant, indicating, as it does, not only the danger of long exposure, but also the rapid rise in infection in the latter part of the day. The results show that *exposure of the tubers should always be avoided*, and that special care should be taken not to expose them in the late afternoon.

Another experiment tried in this matter of exposure was to leave a lot of forty potatoes out in the field from six o'clock in the evening until eight o'clock the next morning. The result was that all of the potatoes were infected, showing the *extreme danger in leaving the potatoes exposed in the field over-night.*

Another series of experiments was based on the fact that it had been found in the laboratory that the worms would leave infested stalks when they began to wither, and enter the tubers. When the potatoes were dug, a number of tubers known to be uninfested were stacked in the field and covered with the infested stalks, and this pile was in turn closely covered with cloth, so that no direct infection by the moth could occur. As a check to this experiment an equal number of uninfested potatoes were stacked in the field, but no stalks were piled upon them. This stack, too, was closely covered with cloth.. Of the potatoes covered with the stalks 70 per cent were finally found to be infested with the worm, while of those not covered with stalks none were infected. Now, it is a common practice in the potato fields to cover the newly-dug tubers with the stalks, and if these stalks are infested the tubers are sure to suffer. Furthermore, even were the stalks uninfested the practice of covering the tubers with them is highly undesirable, as a good shelter for the moth is thus formed. Observations in the field show that the moth is particularly abundant in piles of the stalks, and it may be expected that, taking advantage of this shelter if it is present in the field, it will lay its eggs on the tubers below.

A series of experiments was tried on plants with infested stalks, the infection occurring in this case when the plants were quite old. The experiments were suggested by the fact that as the plant begins to ripen and harden the worms leave the stalks and seek the more succulent food found in the tubers in the ground. The plants selected for these experiments were watched quite closely, and one week before time of digging the heads were cut off just beneath the ground. These heads, with the larvæ still in them, were removed and destroyed. When these hills were dug the potatoes were found to be uninfested, though the check hills with worms in the stalks were infested, the worms having left the stalks and entered the tubers. It was also found that the potatoes in these decapitated hills were, if anything, better and larger than those in the check hills in which the heads remained undisturbed.

We have, in this matter of *removing and destroying infested heads*, a very promising means of defense against the moth, and one that is easily used in field practice. The cheapest and at the same time the most satisfactory way of removing the heads has been found to be by the use of a knife. The method of procedure is for a man to walk along a row, and when an infested plant is found by him to cut it off just beneath the surface of the ground. With a little practice the infested plants will be easily recognized from their somewhat wilted appearance. Other men follow the cutters, gathering up and removing the stalks from the field. These stalks should be placed in piles and covered with a few inches of earth, and fermentation and heating soon following, the larvæ are destroyed. The piles of decayed vegetable matter may be spread over the field and plowed-in, thus enriching the soil.

All of the experimental work in the field indicated the necessity of avoiding exposure of the potatoes as completely as possible, and where this non-exposure policy was fully carried out it was found to eliminate entirely this source of infection.

The conclusions arrived at in the work outlined above were confirmed by the results obtained in another plot of potatoes planted on the Station grounds, but for purposes other than the study of the potato-worm. This plot was also seeded with Oregon Burbanks, and the work done upon it was exactly that which prevails in ordinary farm practice. No particular care was taken in hilling, and exposure at digging was not in any way guarded against. The yield of this plot was practically worthless, 75 per cent of the potatoes being wormy, and yet the original danger of infection was no greater than in the case of the experimental plot.

The results obtained from these exposure experiments led us to another series of investigations. It was noted that the moth was almost sure to find the potatoes if they were in the field, and the question arose whether they would winter in potatoes left in the field. To decide this question a number of infested tubers were left out of doors in gauze-

covered receptacles, but exposed to all weather conditions occurring through the winter. Many of these potatoes rotted completely before the winter passed, but some of them remained in sound enough condition to carry the insects through the winter, and far enough into the spring for the young potato plants to be sufficiently grown to furnish a feeding-place for the larvæ. This would indicate that if waste potatoes were left in the field after digging, the moth would be carried over the rainy season in them, and this is just what seems to have happened in the following case. In the course of this investigation an isolated field of potatoes three acres in extent was found to be badly infested with worms, so badly, indeed, that the tubers were wholly unsalable. The field is owned and worked by a gentleman who runs a country store in a near-by village, and its history was obtained from him. In 1899, the crop was good and not wormy. In 1900, some worms in the potatoes and some complaint from buyers. In 1901, potatoes so wormy as to be unsalable. Methods of planting, cultivation, etc., the same each year. Soil a sandy loam, well drained. Small and waste potatoes and tops always left on the ground and plowed-in. An investigation of the neighborhood disclosed a small amount of "night shade" (*Solanum nigrum*), but hardly enough to more than account for the original infection. There was always a number of potatoes on the ground when seeding began. The progressive infestation noted in this field, which is an example of many fields, was evidently due to this item of bad farm practice, viz., leaving the waste product on the ground.

As a corollary to the results noted in this case, care should be taken *never to use infested seed potatoes*, as the moth is more than likely to come out from them in force, in time to infect the young plants; and, besides, the best farm practice is to use the largest and most vigorous potatoes as seed. In infested potatoes the worm has taken so much of the substance and thus robbed the young plant of so much of the stored nutriment that it will be correspondingly weak, and will to this extent more quickly succumb to the attack of the worm. It is also generally conceded that in an insect attack the less vigorous the plant the more likelihood that the insect will choose it to work upon.

Storage Experiments.—The experiments carried on with stored potatoes were intended, first, to determine the life history of the insect (see p. 12); second, to discover whether the life of the pest could be continued through several generations or indefinitely without the adult having access to food; and finally, to determine what means could be used most practically to stop the infection in the potatoes if it were found that breeding did take place freely among the stored tubers. To initiate these experiments infested potatoes were obtained and placed in gauze-covered receptacles, and the emergence of the moths noted. When the

moths were quite numerous in these receptacles fresh potatoes that were known to be uninfested were introduced. These potatoes were marked so that they could be easily identified at any time, and sooner or later they were always found to be infested, thus proving that the moths could and did breed in storage, and that the damage from them was continuous and progressive. The study of the life of the insect (see p. 12), carried on as it was from the end of one growing season to the end of another, eleven months later, proved that this breeding in storage could extend over several generations—four, as noted in this investigation. This continuance of the moth under storage conditions proved, also, how numerous the progeny of a single pair may become in a few months, for at no time was any disease noted among them, nor was any parasitization observed, and their life work seemed to be carried on practically unhindered.

That the female moth may lay twenty-two eggs has been noted, and considering that half of the eggs laid will produce moths of the same sex, we find the progeny of a single female will, if food is present, number at the end of six months some 15,000 moths ready to oviposit upon any potato plants that may be present.

Of course, there would be natural checks to the moth when its life is carried on out of doors and when having to contend with unfavorable weather-conditions. Two of the breeding-cages used were not interfered with at all from the first of November, 1900, to the last of March, 1901. Ten potatoes were in each of these cages, and when they were finally abandoned the potatoes had sent out sickly sprouts and these sprouts had been killed by the worms working in them. The potatoes themselves were honeycombed with the burrows of the worms, and were so shriveled as to be hardly recognized as potatoes. Some of them had rotted, but by maintaining dry conditions as far as possible most of them had escaped decay. The dead moths in these cages were not counted, but they were numerous enough to fill a half-pint cup, proving that the breeding was carried on in confinement under loose storage conditions.

To decide whether the progressive infestation went on if the tubers were packed as in sacks, two ten-pound lots of potatoes were put up in ordinary jute sacking. One of these lots had no infestation, while in the other lot several infested tubers were placed. These two sacks were put close together in a gauze-covered box, and left for three months. On examination at the end of this time five infested tubers were found in the sack that was originally uninfested, and in the other, the originally slightly infested sack, hardly a good uninfested potato was found. That the infection may spread in sacked potatoes and from one sack of potatoes to another in the same pile cannot be doubted.

Experiments with Carbon Bisulfid.—It having been conclusively shown in this investigation that breeding went on rapidly in the stored potatoes, methods of destroying the pest were sought for—methods that would be effective even when the potatoes were piled "heavy" in the storerooms. We believe that there is no way of reaching the worm when it is once in the potato, except the destruction of the potato itself. A potato that is wormy may be looked upon as hopeless, and should be rendered harmless in the spreading of infection, by being boiled and fed to hogs or destroyed in some other way. But it is impossible in the generality of cases to destroy or even find these infested potatoes before they have spread the infection, and so the question reduces itself to stopping the latter without attempting to find and destroy the individual tubers that are affected. Both the pupæ and the newly-emerged moth are easily killed, and it was considered that in these stages the vulnerable point was to be found.

Numerous experiments were made to test the susceptibility of the chrysalis to the fumes of carbon bisulfid (CS_2), and these proved that we have in this substance the means of controlling the insect, so far as the infestation in stored potatoes is concerned. These experiments were made in the following manner: Potatoes were taken with pupæ on them of all ages, from those which had just spun up to those just ready to emerge. These potatoes were placed in a tight box and a varying amount of carbon bisulfid put in a shallow dish on top of them, and then a close cover put on the box. This "bin" was allowed to stay closed two days, and then the potatoes with their pupæ attached were removed to the gauze-covered cases and closely watched. Every chrysalis was dead, as was shown by no moths emerging, though the observations were kept up for eight weeks.

The amount of carbon bisulfid used in this and the following experiments was not measured, though it was in no case more than one drachm to the cubic foot of space, and the amount used was in all cases more than enough to kill all chrysalids. The amount recommended to be used, under the head of "Remedies," is based on the calculations made for the disinfection of grain in bins.

These experiments were followed by others, in which the life-history study was used as a guide for the time to apply the poison. In each experiment there were used a number of infested tubers in which the worms had not begun to make their cocoons. It was supposed that there might be larvæ of all ages in these potatoes, and also possibly some pupæ on them, so the tubers were treated with the bisulfid as soon as placed in the "bin." Two weeks later the potatoes were again treated with bisulfid, and this was repeated twice more at intervals of two weeks, when it was considered that probably all the worms had

spun and all the chrysalids were killed. This proved to be the case, for the infestation in this lot was ended, and though the once infested potatoes finally rotted, this did not occur until ample time had elapsed for the moth to appear, if any of the insects had remained alive. Several experiments were tried in this line with a less number of treatments, and while some were successful where but three applications of bisulfid were made, this reduction of the number of applications was not always a success, for the infestation continued in some cases.

The fact before noted, that under ordinary storage conditions there is more or less lapping-over of generations, must be borne in mind, and if infestation of the tubers is suspected or noted, then a treatment immediately on their being placed in storage is imperative. This first treatment kills all pupæ that may have appeared before this time. The second treatment cares for all the chrysalids that may appear after the first treatment, and does not give time for the moth to emerge from them; the third treatment disposes of the pupæ that may appear after the second treatment; while the fourth treatment finishes all possible late pupæ. This is under the supposition that potatoes unexposed to the moth after digging, are being dealt with. If the potatoes have been exposed after digging there is a possibility that there will be eggs on the potatoes treated, and a fifth application of carbon bisulfid becomes necessary. This fifth treatment should be given at the end of the eighth week of storage. So completely successful was the work with the bisulfid that in none of the experiments where it was used did a single chrysalis escape, and in no case did its persistent use fail to stop infestation.

REMEDIES.

In discussing the experimental work under various headings, remedies have been noted that proved successful in practice, and the various recommendations here made have been tested under working conditions in actual practice. Attention, however, must be drawn to the fact that in any case of infestation there comes a point where remedies, that at one time would have been successful, are useless. So, in handling an insect attack, we must not wait until the insect is out in force and then try to rid our crops of the pest, but the fight must be begun when the invasion is in its incipiency, and beginning thus we may confidently expect our efforts to lead to success. The farmer who carefully watches his potato field, and is ready to begin the battle against the moth when it first appears, has an easier fight than he who waits until the full army of the moth is in array against him; and so it is all along the line until the potatoes are marketed.

By vigilance and watchfulness, as well as by the use of discrimination in suiting the remedy to the conditions, the insect may be controlled, even in the localities worst affected.

Food Plants Should Be Destroyed.—As has been before stated, the insect, according to all observations, confines itself in its larval form to solanaceous plants, and its great injury is done among the cultivated representatives of this family, notably in the potato and tobacco. It has been reported as feeding and breeding among the wild members of the family, and this feature of its career was considered of value in this investigation, because if any of these wild members were to be found near the cultivated plants they would constitute a good breeding-place for the insect and a point for infection to originate. We have in California much of the so-called "night shade," the *Solanum Douglasii*, *S. nigrum*, *S. umbelliferum*, and *S. Xanti*, and where these plants are found the insect is sure to be found also, as collections made among and near them have shown. Furthermore, collections, especially at lights, made hundreds of feet from any solanaceous plants, have shown the moth to be present, thus indicating its ability for flying quite long distances. This, together with the fact that the insects are not confined to the cultivated plants of the family *Solanaceæ*, but attack the wild representatives also, at least suggests that any patch of such plants as the night-shades constitutes a menace to any potato plants in the neighborhood, and that all such patches should be destroyed.

Light-Trapping.—It has been noted (p. 17) that the moth is easily taken in large numbers at lights, and in the use of light-traps we have a most effective method of killing it. The use of the light-trap, too, is a most satisfactory way of finding out whether the moth has begun to work in a potato field, as two or three such lights scattered about the field will surely show specimens, if any are flying. If the moth is found to be present, then the traps might be placed in the field at intervals of 100 feet or so, and kept in action each night until moths fail to be taken at them. It seems most probable that the persistent use of these traps at this time will greatly reduce the possibilities of infestation. There are various forms of these traps on the market, and some of them are quite effective, though probably not more so than the common lantern trap, made by soldering a torch body into the center of a shallow pan and attaching beneath a tin ferrule, by which it is supported on top of a stake driven into the ground.

Destroy Infested Stalks.—If infestation of the plants has begun before note has been made of the presence of the moth in the field, then in addition to the use of the lights suggested above it would without doubt amply pay to go carefully over the field and cut off the infested stalks just below where the injury is apparent, and remove and destroy them (see p. 20). The infested plants will be recognized from their evident wilting, and this work can be done quite rapidly. When a man has

become somewhat expert in recognizing the trouble, he will be able to remove all infested stalks from a row in about twice the time it would take him to walk the length of the same row. The object of this work is to stop the infestation before it becomes general; but it is evident that much watchfulness is required in detecting the attack in its incipiency. If the plants showing stalk-infestation are not too young, the removal of a part of the stalk does not materially hurt the plant as a tuber-producer. If the infestation is noted in an old plant, then the whole head may be removed a short distance beneath the surface of the ground a week or ten days before digging, thus effectively disposing of the worms, but in no way injuring the tubers (see p. 20). The necessity of destroying it at this time depends upon the fact that the worm may either come out from its burrow and pupate and then transform to the moth and be ready to multiply the damage many-fold, or may leave the stalk and work its way to the tubers in the ground.

Careful Hilling.—One of the most effective methods of preventing infestation of the tubers where flat culture is not imperative, is to be found in careful, compact hilling. Too often in our large potato fields where hilling is the practice, it is done so carelessly that many of the tubers are not covered completely, or if covered it is by a very thin and dry layer of earth. The potatoes that are not completely covered are attractive to the moth and are almost sure to be infected, while those that are thinly covered may be easily reached by the worm when it leaves the stalk.

If the covering over the potatoes in the hill is composed of lumpy material, the moth itself may find its way to the tubers, and infestation will follow. The greatest care should therefore be taken in this matter of hilling if the moth is about, as experiment has shown that where careless hilling is the practice great damage will ensue (see p. 18). When flat culture is practiced the same protection of the tubers should be accomplished by deep planting, supplemented, where necessary, by slight hilling at the last cultivation.

Avoid Exposure While Digging the Potatoes.—The potatoes should not be exposed to a possible visit from the moth while they are being dug. The moth at this time is ready for the potatoes and will find them if they are exposed for any great length of time, and especially if they are left exposed over-night. The practice of covering the newly-sacked potatoes with the potato tops to shade them, should also be avoided, and care should be taken to remove the sacked potatoes within, at most, four hours after digging. If such removal is impossible, then the sacks of potatoes should be stacked in the field and covered closely with a cloth of some sort to ward off possible visits from the moth (see p. 19).

Clean Up the Field After Digging.—The old heads and waste potatoes should be destroyed in the field after the crop has been removed, especially if the insect is at all in evidence, as this waste material offers a good breeding-place for the moth and may serve to carry the infestation forward to the next crop (see p. 14). The most satisfactory way to clean up a field of any large size is to turn sheep into it to pasture. The sheep are even more effective in their work than hogs, and seem to find every potato in the field, even going so far as to paw up any tubers that may have been missed in the digging and have remained covered with earth. In cases where a field has been flooded for two or three weeks the infestation seems to have been thoroughly destroyed. Any method that will destroy the waste potatoes on and in the ground will be effective, but this destruction must be accomplished if the ground is to be used for potatoes the ensuing year. Where this cannot be done, a rotation of crops is suggested as the only safe means of procedure, and it is effective because the worm feeds solely on solanaceous plants. Attention is here again called to the fact that the tubers used as seed must be free from infestation, as the moth will breed from such infested potatoes and will soon overrun the field.

Control of the Moth among Stored Potatoes.—The attack of the moth is the cause of great loss among stored potatoes, and it is probable that it is the damage done at this time that has been most observed. It is in the storerooms that surrounding conditions can be most easily controlled, but it is also here that the attack is most concentrated, and therefore at this time the work against it should be prosecuted with the greatest vigor.

Attention has been called to the use of carbon bisulfid (see p. 23) as an effective weapon against the moth when it is in the chrysalis form, and the careful use of this agent will undoubtedly stop the infestation among the stored tubers. To use the carbon bisulfid to any advantage the tubers must be placed in tight rooms or bins made in such a way that when the gas is being generated little or no leakage may occur. A bin made of tongue-and-groove lumber, with a top cover fitting quite closely, is to be considered the best for disinfecting small quantities. When larger quantities are to be treated, they may be piled in a tight room; the exact dimensions, the cubic space, of the room or bin must be known, as the amount of the carbon bisulfid used is determined by this cubic content.

It has been found in fighting insects in stored grain that one pound of the bisulfid to one thousand cubic feet of space is effective, but as potatoes are sacked this amount had better be increased to one and one half ($1\frac{1}{2}$) pounds, on account of the large air spaces occurring between the sacks. As far as our experiments go, they have shown that the gas

generated diffuses thoroughly among sacked potatoes, and that the chrysalids are killed here quite as well as when the tubers are not sacked. Five treatments of the carbon bisulfid should be given to each lot of potatoes, in this order: A treatment when the tubers are first stored; a second, third, fourth, and fifth treatment at intervals of two weeks (see p. 24). In a room or bin that measures 10 feet each way, we have 1,000

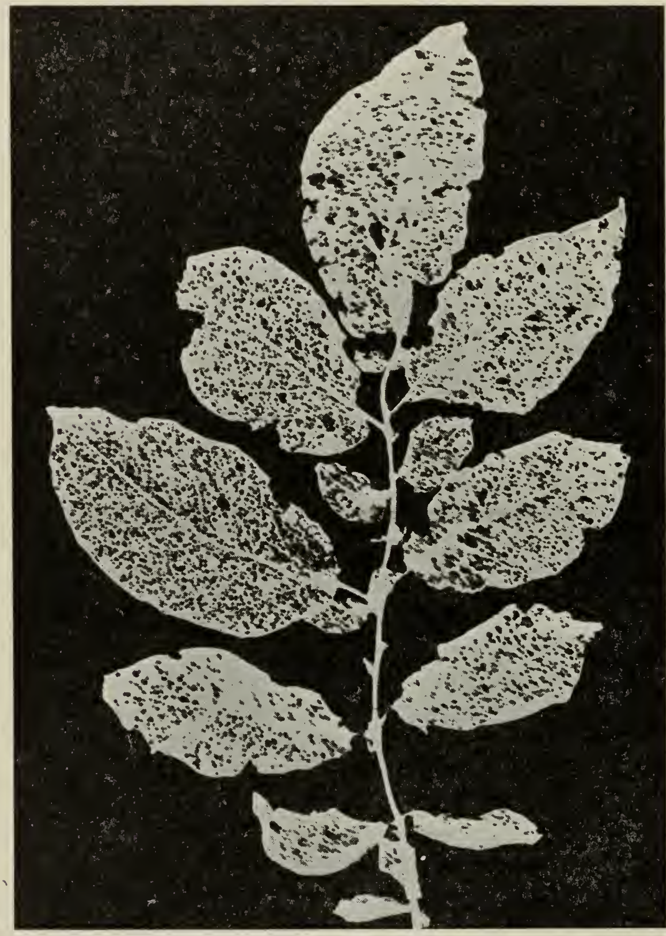

FIG. 8. The work of the Flea Beetle.

cubic feet of space, which will hold from 200 to 250 sacks of potatoes, and five thorough treatments of the contents will require 5 to 7½ pounds of the carbon bisulfid.

The material should be placed in shallow dishes on top of the potatoes, and then all should be tightly shut in. The liquid carbon bisulfid becomes a gas on being exposed to the air, and this gas being heavier than the air, sinks to the bottom and soon fills the spaces between the potatoes

with its poisonous fumes. The gas is *highly inflammable*, and the greatest care must be exercised in handling it; be sure that no lights of any kind are near by at the time, or the results will be disastrous. The gas will kill all the chrysalids and all the adult moths present at the time, and will not injure the tubers.

OTHER PESTS.

In the course of this investigation of the moth *G. operculella* and its damages to the potatoes in California, certain other pests have been noted as causing more or less injury to this crop, and we briefly summarize these observations here.

Flea Beetles.—In the experiment plot on the Station grounds some damage was done to the plants by one of the flea beetles (*Epitrix subcrinita* Lec.), and in certain of the fields visited the damage done by another representative of the group, *E. hirtipennis* Mels., was quite large. These insects, which are true leaf-feeders, belong among the beetles in the family *Chrysomelidæ*. They are minute (1.5 mm. long), generally black or dark brown, ochreous-tinted beetles. The thoracic region and the elytra are regularly pitted. The pits are the seats of minute hairs (see Fig. 9). Their general appearance and their habit of jumping from their position on the leaf by means of their thickened hind legs, remind one strongly of a flea, whence the common name, flea beetles. They eat small round holes in the potato leaf, and when the attack is severe the leaves become so riddled with the punctures as to be able to function as leaves no longer. Figure 8 gives a good idea of the character of their work. The attack on the field from which the leaf here figured was taken was so severe that the value of the crop was reduced fully 50 per cent.

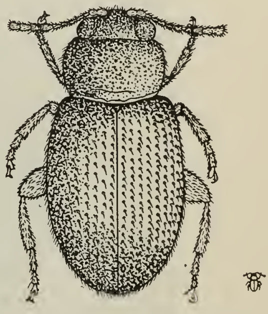

FIG. 9. *Epitrix hirtipennis* Mels. Right hand figure gives actual size of insect.

As stated above, this beetle is a leaf-feeder, and it can therefore be controlled by the use of Paris green, either dusted on the plant or used as a spray. The spraying material should be made up of one pound of pure Paris green to one hundred and fifty gallons of water, and may be cheaply and effectively applied to the plants by the use of a tank and spray pump on a wagon. The spray should be used as soon as the attack is observed, and, unless it is very violent, one application will probably be found sufficient to keep the beetles below the danger limit.

Stenopelmatus, incorrectly called Yellow Ground Cricket, Sand Cricket, Jerusalem Cricket, Common Beetle, and Potato Bug.

There are frequently noticed in the potatoes places where the tubers

are bitten into as though mice had been gnawing them. These wounds are quite evident in some specimens, and render the tubers attacked unmarketable as a first-class product (see Fig. 6). The insect causing this damage is a large and clumsy member of the family to which the katydids belong. It has a large and horny head and a soft and heavy abdomen. Its movements are awkward and slow, and its color ranges from yellow to brown. It never has wings. It will be at once recognized from the figure No. 10. These insects seldom become numerous enough to do any large amount of damage, but nevertheless they should be killed, crushed, wherever found. They can be trapped by placing bits of board upon the ground in the field. The insects get beneath these boards and may be easily killed there.

Fig. 10. Stenopelmatus.